Crack Propagation Behaviour of Polyurethane Thermoplastic Elastomers in Cyclic Fatigue

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Requirements of waste reduction and environmental sustainability caused a renewed interest for thermoplastic elastomers (TPE's). TPE's are an interesting class of re-processable materials with intermediate properties between those of conventionally vulcanized elastomers and thermoplastics, such as, flexibility, high reversible extensibility, easy shaping and fast processing. Although TPE's have seen a fast diffusion in the last 20 years, few studies have appeared on the cyclic behaviour in fatigue(Mars & Ellul, 2017). TPE's are typically composed by at least two components at the operating temperature: a hard and solid component and an elastomeric soft component(J.W.C Van Bogart, A. Lilaonitkul, 1979). The presence of phase separation (at the submicron scale) between those two components provides physical crosslinking and dissipative mechanisms so that TPE's can be used without any chemical crosslinking and in unfilled state.

We investigated the crack propagation in cyclic fatigue of two commercial polyurethane/ester multi-block copolymers (TPU) with similar Young Modulus and strain lower than 100%. The cyclic fatigue resistance of the materials were characterized by the crack propagation rate per cycle (dc/dn) in a pure shear sample as function of the applied energy release rate $\mathcal{G}$ in each cycle (Thomas 1959) . The fracture energy for monotonic load was evaluated with the same pure shear geometry adopting the procedure used by Rivlin and Thomas (Rivlin & Thomas, 1953) at different temperatures and strain rates.
For one of the TPUs the cyclic loading results in almost no propagation with a clear blunting of the crack accompanied by a progressive damage ahead of the crack, even for thousands of cycles at moderate level of applied strain. In similar conditions, the second tested TPU shows an evident propagation of the initial crack at a rate that is comparable to that obtained for conventional filled elastomers (Mzabi, Berghezan, Roux, Hild, & Creton, 2011). The difference in the fatigue behaviour of the two TPU cannot be explained by obvious differences in the monotonic fast fracture that is instead quite similar for both TPU.

The observed crack blunting in one of the TPUs confirms that the details of the TPU's architecture resulting in a microphase separation can result in a very good resistance to crack propagation in cyclic conditions. However, the sole knowledge of the fracture energy of the TPU in monotonic loading is not sufficient to predict their lifetime in repeated cyclic loading. This suggests that additional or different dissipation mechanisms are active in the two TPU's ahead the crack tip when they operate under cyclic stress condition. To address this question we will investigate on the morphology at the crack tip using the techniques of X-Ray and Digital Image Correlation(Roux, Réthoré, & Hild, 2009) the strain field in front of the crack tip.